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ABSTRACT

This paper presents the procedures, results and conclusions of a study designed to determine whether three different methodological approaches to the laboratory for a general education physical science course would lead to the same behavioral outcomes. Students enrolled in the physical science course were randomized into one of three laboratory treatment groups; a highly structured scheduled lab, an audio-tutorial type free lab, and a loosely structured home lab. Behavioral changes were assessed through instructor-written unit tests and the Test On Understanding Science (TOUS). Data were obtained for 140 students during the first experimental period, and for 195 students during the second experimental period. The results indicated that (1) no significant differences existed among the lab groups in terms of their cognitive knowledge of science, (2) for the first experimental period, no significant differences existed among the groups with respect to their understanding of science as measured by TOUS, (3) for the second experimental period, significant differences existed among the groups on TOUS scores, and (4) the free lab and home lab groups scored significantly higher on TOUS than the scheduled lab groups. (LC)

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THE EFFECT OF THE LABORATORY ON THE COLLEGE STUDENTS' UNDERSTANDING AND KNOWLEDGE OF PHYSICAL SCIENCE

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PART I: INTRODUCTION

I. The Problem.

The increase in college enrollments during the past decade has brought about changes in the college curricula, especially in the general education courses. In many instances institutions of higher education have attempted to accommodate increasing numbers of students through large lecture classes. Perhaps more seriously, the enrollment of large numbers of students in science courses designed for the non-science major has "forced" the discontinuance or severe curtailment of the accompanying laboratory component of these general education science courses.

Also, in some institutions such courses were developed as non-laboratory survey courses. Now the influx of large numbers of students and limited physical facilities and instructional materials has made it difficult, or seemingly impossible to realize a change from a non-laboratory course to a laboratory-oriented course. Many developing two-and four-year colleges are experiencing these difficulties.

Therefore, if means were discovered whereby a student could perform a laboratory exercise using simple, inexpensive equipment at a time and place convenient to the student and which would change the student's behavior in the same manner as a regularly scheduled laboratory in a science building, the laboratory activities might become the context for a valid science course for the non-science student.

Thus, the primary concern of the researchers was to explore the effectiveness of three different laboratory approaches for accomplishing the same specified behavioral outcomes. The following statement of objectives will specifically delineate the intents of the research:

1. To discover whether individualized, home laboratory experiences are as effective as the scheduled laboratory experiences for the development of specified cognitive skills.

2. To discover the relative effectiveness of a particular laboratory treatment upon the student's development of favorable attitudes toward science and an understanding of the scientific enterprise.

Effectiveness as stated in the objectives will be shown by or defined in terms of (1) accomplishing the instructor-written behavioral objectives of subject matter knowledge as measured by instructor-written unit tests, and (2) an understanding of the entirety of the scientific enterprise as measured by the Test On Understanding Science.

II. Related Research.

A review of the science education literature reveals a paucity of research related to the unequivocal role of the laboratory in a science course. Yet few scientists and science educators would disagree with the necessity of the laboratory or field experience in an introductory science course which purported to be valid. In the same regard, it seems germane to indicate what Brandwein, Watson, and Blackwood[1] have suggested concerning the role of the laboratory: the importance of the laboratory work, which is expensive with respect to student and instructor time, special physical facilities, and apparatus, is embodied in the realm of learning "how the scientist works."

However, there have been a number of research projects conducted by Kruglak[2] and associates. In the early 1950's Kruglak conducted a number of studies concerning the effects of the laboratory work upon the behaviors of college students in an introductory physics course. Using both "paper-and-pencil" tests and "performance" tests, Kruglak concluded that "performance tests measure instructional outcomes other than those measured by conventional achievement tests . . . ."

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[1]Brandwein, P.F., Watson, F.G. and Blackwood, P.E., Teaching High School Science: A Book of Methods. New York: Harcourt, Brace, 1958, p. 279.

[2]Kruglak, H., "Some Behavior Objectives for Laboratory Instruction," American Journal of Physics, 1951, 19, 223-225.

Kruglak, H., "Experiemntal Outcomes of Laboratory Instruction in Elementary College Physics," American Journal of Physics, 1952, 20, 136-141.

Kruglak, H., "Achievement of Physics Students with and Without Laboratory Work." American Journal of Physics, 1953, 21, 14-16.

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Kruglak, H., "Measurement of Laboratory Achievement." American Journal of Physics, 1955, 23, 82-87.

Kruglak, H., "Evaluating Laboratory Instruction by Use of Objective-type Tests." American Journal of Physics, 1958, 26, 31-32.

Kruglak, H. and Goodwin, R. A., "Laboratory Achievement in Relation to the Number of Partners," American Journal of Physics, 1955, 23, 257-264.

Lahti[3] conducted research in 1956 concerning the effect of various approaches to the laboratory component of a college level physical science course. Utilizing 338 students, four laboratory approaches were used: (1) an inductive-deductive or problem solving approach in which an answer sought was not previously known; (2) a case-history approach in which the answer sought was known; (3) a recitation-discussion approach; and (4) a standard "get the right answer" approach. Three tests were designed to assess the relative effectiveness of each approach: (1) an "Interpretation of Data" test, (2) a "Design an Experiment" test, and (3) a "Performance Test." Even though Lahti found no statistically significant differences on the aforementioned tests, the inductive-deductive group scored highest on each of the three tests.

The aforementioned research projects appear to be exemplary of the kinds of research being conducted to explore the efficacy of different instructional approaches to an introductory college science course. As a whole they reflect the fact that instructional outcomes are determined primarily by the instructional strategies employed.

In the past decade a number of national curriculum projects have been produced through a concerted team effort of educationists and scientists. All are characterized by a strong laboratory orientation. It is the feeling that this is as it must be. But it appears as if research is needed to ascertain more definitively how much and what type of laboratory experience leads to what student behaviors.

III. Definition of Terms.

The research project was designed to explore the relative effectiveness of three different laboratory approaches for accomplishing the behavioral objectives defined for the general education physical science course at Kansas State Teachers College, PS 214 Physical Science. The three laboratory treatment groups, which were determined by random methods from the entire enrollment in PS 214, were referred to as the scheduled lab, free lab, and home lab groups. Certain terms peculiar to the research project, and unique to the research context provided by Kansas State Teachers College will be defined.

PS 214 Physical Science: PS 214 is the general education course offered at K.S.T.C. to satisfy requirements for the BSE or BA degrees for the non-science major. The course treats in an interdisciplinary manner concepts from the classical areas of astronomy, physics, chemistry, and geology. For purposes of the project, the class met three hours per week for large group

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[3]Lahti, J., "The Inductive-Deductive Method and the Physical Science Laboratory," Journal of Experimental Education, 1956, 24, 149-163.

instruction, one hour per week for small group activity, and two hours (or the equivalent for the "home lab") per week for laboratory activity.

Scheduled Lab: For purposes of this study, the scheduled lab refers to that group of students who gained their laboratory experience through a regularly-scheduled, two-hour laboratory section. The scheduled lab group utilized the laboratory exercises developed in the past by the Physical Science Division at Kansas State Teachers College. The two-hour laboratory period was introduced by one of the researchers with a pre-laboratory discussion of the laboratory objectives, procedures, and peculiarities of certain equipment or materials to be used. The student then adjourned to the adjacent lab to perform the experiment under the supervision of the instructor and/or laboratory assistant.

Free Lab: This laboratory treatment group utilized the same laboratory exercises, equipment and facilities as the scheduled lab group. However, the pre-laboratory instruction was accomplished through the use of audiotapes and visual materials. The students assigned to this laboratory treatment group were free to come to the laboratory on the specified lab day at a time of their choice. A student laboratory assistant was present at all times to offer assistance to the students.

Home Lab: This laboratory treatment group satisfied its laboratory requirements through lab exercises designed to utilize simple equipment easily provided in kit form. The student was provided a written laboratory exercise and a kit of equipment and/or materials not normally found in his school residence. He performed the experiment at his convenience, generally at his school residence. The home lab hardware and software were designed to provide a set of experiences commensurate with those of the scheduled and free lab groups.

Test On Understanding Science (TOUS)[4]: TOUS is an evaluation instrument containing sixty items which is designed to measure three areas of science understanding:

(1) Scale 1 - Understanding about the scientific enterprise (18 items),
(2) Scale 2 - Understanding about scientists (18 items), and
(3) Scale 3 - Understanding about the methods and aims of science (24 items).

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[4]Educational Testing Services, Princeton, New Jersey 08540, Form W was copyrighted 1961 by W. W. Cooley and Leopold E. Klopfer.

Instructor Written Tests: These were examinations developed by the instructors (the co-directors of the research project) and designed to assess the student's subject matter knowledge. The examinations contained fifty, multiple choice items (except the final examination which contained one hundred items) and were based upon the behavioral objectives which the students received at the beginning of each of the five instructional units of the course.

IV. Hypotheses.

The following hypotheses were formulated in null form to be subjected to an analysis of covariance to determine if significant differences occured among treatment groups:

1. There is no significant difference in the attainment of the specified cognitive skills as measured by the instructor written tests between those students in the "scheduled lab" and those students in the "free lab."

2. There is no significant difference in the attainment of the specified cognitive skills as measured by the instructor written tests between those students in the "scheduled lab" and those students in the "home lab."

3. There is no significant difference in the attainment of the specified cognitive skills as measured by the instructor written tests between those students in the "free lab" and those students in the "home lab."

4. There is no significant difference in the understanding of science as measured by TOUS between those students in the "scheduled lab" and those students in the "free lab."

5. There is no significant difference in the understanding of science as measured by TOUS between those students in the "scheduled lab" and those students in the "home lab."

6. There is no significant difference in the understanding of science as measured by TOUS between those students in the "free lab" and those students in the "home lab."

If the analysis of covariance indicated any significant differences, a t-test was used as a test of significance to determine which group or groups were contributing to the significant F ratio. The null hypothesis were rejected if the F test and t-test equaled or exceeded the .05 level of confidence.

The null hypotheses four, five and six are stated in terms of the total TOUS score. This was done since the three scales of TOUS

are based upon a limited number of items, thus, lessening the strength of any conclusion based upon the performance of students on any one scale.

V. Procedure.

During the past few years the general education course at Kansas State Teachers College, Physical Science 214, Physical Science has been structured around a two hour laboratory exercise with four, one-hour lectures each week of the semester. Each lecture section has enrolled from fifty to one hundred students with the accompanying laboratory sections enrolling a maximum of forty students. A lecture section and its companion laboratory sections have been the prime responsibility of a single instructor.

This course and its basic structure served as the framework in which the study was to be conducted. For the semesters beginning in January, 1969 and September, 1969, one of two sections of the course was taught by the investigators as a team of two instructors.

Students enrolling in the experimental classes had a choice of one of two laboratory sections. One of the co-directors was in attendance during the enrollment to maintain as nearly as possible equality of size of the two laboratory sections.

Prior to enrollment of students in the class, procedures for assuring a randomization of students in the three laboratory groups were finalized. A table of random numbers was used to obtain a list of random numbers with which a maximum enrollment of 250 students could be randomly assigned to one of three laboratory treatment groups.

On the first day of class students placed their name and the time of the laboratory section in which they had enrolled on a three by five card. The cards were collected and sorted by the scheduled time of the laboratory section. Each deck of cards was shuffled and numbered consecutively. Those students whose number on their card corresponded with a number in the first third of the selected random numbers list were assigned to the scheduled laboratory, those whose card number corresponded with a number in the second third of the random number list were assigned to the free laboratory, and the last third of the students were assigned to the home laboratory. Students who enrolled late or were not in attendance the first day were assigned to a laboratory group on a rotating basis as they individually arranged for their laboratory assignments with the instructors.

At the close of the first experimental period, complete data was available for forty-seven students assigned to the scheduled laboratory, forty-four students assigned to the free laboratory, and forty-nine assigned to the home laboratory. For the second experimental period, complete data were available for seventy students assigned to the scheduled laboratory, sixty-six students assigned to the free laboratory and fifty-seven assigned to the home laboratory.

Thus, the population for the study consisted of those students enrolling in the section of Physical Science 214 taught by the investigators. This population was randomized into three sub groups or treatment groups and assigned to a particular laboratory treatment.

To ascertain whether or not the objectives of the study were accomplished, two types of evaluative instruments were used to obtain the basic data.

Five unit tests and a final test were constructed by the investigators. These six tests were based on behavioral objectives written by the investigators and made available to the students prior to instruction. The specific aim of these tests was to measure the development of specific cognitive skills with the students.

To assess the students' development of an understanding of science as outlined in the second basic objective of the study, the Test On Understanding Science was selected. The sixty item test is designed to measure three aspects of science understanding:

1. Understanding about the scientific enterprise (Part I, 18 items),
2. Understanding about the scientists (Part II, 18 items), and
3. Understanding about the methods and aims of science (Part III, 24 items).

The information recorded for each student on IBM punch cards included the student's identification number, sex, prior high school science courses, and raw scores on the evaluative instruments.

The data punched on IBM cards was verified by a second keypunch operator and checked against the written card for error. An analysis of covariance was used to determine if any significant differences existed among the groups. The t-test was used to determine significance between groups if the analysis of covariance indicated differences existed among the groups.

PART II: INTERPRETATION OF DATA

As was described previously in this report, data was collected from a total of 333 students during two experimental periods. The data collected for each student participating in the study included five scores on instructor written tests administered during the experimental period of one college semester, the score on the instructor written final examination administered at the end of the experimental period, and the total score and three scale scores on the Test On Understanding Science (TOUS) administered during the last week of the experimental period.

Using random number tables, the students enrolled in PS 214 were assigned to one of three laboratory treatment groups by the instructors. These three groups are the scheduled lab, free lab, and home lab. The statistical presentations are made with reference to these treatment groups and the total or combined group for each experimental period.

Data from the instructor written tests and the TOUS test have been organized into tables which identify one or more of the following: the evaluation instrument, the experimental period, the treatment group, group mean score, group standard deviation, analysis of covariance, F test and its significance, and t-test and its significance.

For the purpose of this study, significant findings are defined as those findings for which the F test and t-test equals or exceeds the 0.05 level of confidence. Any F tests and t-tests equal to or exceeding the 0.01 level of confidence will be considered very significant.

TABLE I

GROUP MEAN SCORES FOR BOTH EXPERIMENTAL PERIODS ON INSTRUCTOR WRITTEN TESTS AND TEST ON UNDERSTANDING SCIENCE

	Scheduled Lab		Free Lab		Home Lab		Total Group	
Instrument	First experimental period	Second experimental period	First experimental period	Second experimental period	First experimental period	Second experimental period	First experimental period	Second experimental period
IWT* #1	29.9	30.1	30.9	31.0	31.1	29.6	30.6	30.3
IWT #2	24.7	25.3	24.3	26.1	24.0	25.8	24.3	25.7
IWT #3	26.2	26.4	25.1	27.1	26.2	25.4	25.8	26.3
IWT #4	26.7	29.0	25.7	30.1	26.6	29.0	26.3	29.4
IWT #5	30.4	29.6	30.4	31.5	28.1	30.4	29.6	30.0
IWF**	54.9	53.5	54.8	55.5	54.3	54.4	54.7	54.5
TOUS Part I	11.0	11.0	11.4	11.7	11.2	11.2	11.2	11.3
TOUS Part II	11.7	11.2	11.9	12.3	11.7	12.3	11.8	11.9
TOUS Part III	12.7	12.1	12.4	13.7	12.7	13.1	12.6	13.0
TOUS Total	35.5	34.3	35.7	37.9	35.5	36.7	35.6	36.2
Number of Students	47	70	44	66	49	57	140	193

* IWT is Instructor Written Test
** IWF is Instructor Written Final

TABLE II

GROUP STANDARD DEVIATIONS FOR BOTH EXPERIMENTAL PERIODS ON INSTRUCTOR WRITTEN TESTS AND TEST ON UNDERSTANDING SCIENCE

	Scheduled Lab		Free Lab		Home Lab	
Instrument	First experimental period	Second experimental period	First experimental period	Second experimental period	First experimental period	Second experimental period
IWT* #1	6.46	6.64	7.88	6.12	6.62	6.97
IWT #2	6.52	6.63	6.75	6.69	6.37	4.62
IWT #3	5.77	6.61	7.29	6.45	6.62	5.64
IWT #4	7.20	7.28	8.21	7.14	6.79	7.05
IWT #5	5.47	7.85	6.63	7.26	6.52	5.93
IWT**	10.71	11.20	11.22	10.86	9.56	10.01
TOUS Part I	2.26	2.81	2.53	2.62	2.03	2.49
TOUS Part II	1.87	2.58	2.38	2.13	2.18	2.20
TOUS Part III	2.57	3.08	3.13	3.74	2.89	2.93
TOUS Total	5.03	6.24	6.70	6.59	4.99	5.85

* IWT is Instructor Written Test
** IWF is Instructor Written Final

Table I shows no great difference in the group mean scores when comparing groups within an experimental period or when comparing the same treatment for the two experimental periods. The greatest differences in mean scores occur between the scheduled lab group and the free and home lab groups on Part II, Part III, and the total score of the TOUS for the second experimental period.

Since standard deviation is an index of the dispersion of scores about the mean of a distribution, the data presented in Table II gives an indication of the variation of each group from its mean for all tests for both experimental periods.

For the first experimental period, the free lab group had the largest standard deviation on nine of the ten tests or parts of tests. The home lab group had the smallest standard deviation on five of the ten tests and in no case was the standard deviation the greatest. It had been assumed by the investigators that the standard deviation would be inversely related to the extent of structure of the laboratory treatment groups. That is, the scheduled lab was the most structured and thus would have the least variation while the home lab with a minimum of structure would have the greatest variation. This assumption was not supported by the data shown in Table II. Data for the second experimental period shows that the home lab group had the smallest standard deviation in eight of the ten cases.

TABLE III

AN ANALYSIS OF COVARIANCE ON THE INSTRUCTOR WRITTEN TESTS AMONG THE SCHEDULED LAB, FREE LAB, AND HOME LAB GROUPS FOR BOTH EXPERIMENTAL PERIODS

Test	Experimental Period	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test	Significance
Test I	I	Group	2	38.79	19.39	.39	N.S.
		Within Group	137	6851.36	50.01		
		Total	139	6890.14			
	II	Group	2	63.35	31.68	.72	N.S.
		Within Group	190	8333.98	43.86		
		Total	192	8397.33			
Test II	I	Group	2	10.56	5.28	.12	N.S.
		Within Group	137	5993.29	43.75		
		Total	139	6003.85			
	II	Group	2	23.28	11.64	.31	N.S.
		Within Group	190	7244.04	38.13		
		Total	192	7267.33			
Test III	I	Group	2	34.82	17.41	.39	N.S.
		Within Group	137	6057.03	44.21		
		Total	139	6091.85			
	II	Group	2	88.18	44.09	1.10	N.S.
		Within Group	190	7616.15	40.08		
		Total	192	7704.33			
Test IV	I	Group	2	28.59	14.30	.26	N.S.
		Within Group	137	7666.95	55.96		
		Total	139	7695.54			
	II	Group	2	50.97	25.49	.49	N.S.
		Within Group	190	9903.10	52.12		
		Total	192	9954.07			
Test V	I	Group	2	171.93	85.97	2.17	N.S.
		Within Group	137	5430.35	39.64		
		Total	139	5602.29			
	II	Group	2	122.82	61.41	1.19	N.S.
		Within Group	190	9795.37	51.55		
		Total	192	9918.19			
Final	I	Group	2	8.40	4.20	.04	N.S.
		Within Group	137	15412.49	112.50		
		Total	139	15420.89			
	II	Group	2	132.39	66.20	.56	N.S.
		Within Group	190	22283.75	117.28		
		Total	192	22416.15			

The data from the analysis of covariance on the Instructor Written Tests for both experimental periods is shown in Table III. None of the F tests were significant at the defined level of significance. Thus, the data indicates that there was no differences among the groups in terms of the factors measured by the Instructor Written Tests.

TABLE IV

AN ANALYSIS OF COVARIANCE ON THE TEST ON UNDERSTANDING SCIENCE AMONG THE SCHEDULED LAB, FREE LAB, AND HOME LAB GROUPS FOR BOTH EXPERIMENTAL PERIODS

Test	Experimental Period	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test	Significance
Part I	I	Group	2	2.75	1.38	.26	N.S.
		Within Group	137	725.04	5.29		
		Total	139	727.79			
	II	Group	2	17.00	8.50	1.19	N.S.
		Within Group	190	1361.44	7.17		
		Total	192	1378.44			
Part II	I	Group	2	1.95	.98	.21	N.S.
		Within Group	137	647.62	4.73		
		Total	139	649.57			
	II	Group	2	51.97	25.99	4.73	V.S.
		Within Group	190	1043.16	5.49		
		Total	192	1095.13			
Part III	I	Group	2	3.40	1.70	.20	N.S.
		Within Group	137	1149.78	8.39		
		Total	139	1153.17			
	II	Group	2	92.14	46.07	4.22	S.
		Within Group	190	2075.53	10.92		
		Total	192	2167.67			
TOUS Total	I	Group	2	1.16	.58	.02	N.S.
		Within Group	137	4394.63	32.00		
		Total	139	4385.79			
	II	Group	2	468.68	234.34	5.91	V.S.
		Within Group	190	7537.88	39.67		
		Total	192	8006.56			

Table IV presents the data resulting from the analysis of covariance on the Test On Understanding Science for both experimental periods. The F tests resulting from the analysis for the first experimental period are not significant. However, for the second experimental period significant results (P = .05) were found for Part III, Understanding about the aims and methods of science. For Part II, Understanding about the scientists, and the TOUS Total, the F test indicates very significant results (P = .01).

To determine the significance of differences between groups, a t-test was used on the data. This data is presented in Table V.

TABLE V

t - TEST OF SIGNIFICANT F TESTS FROM THE ANALYSIS OF COVARIANCE ON THE TOUS

Test	Experimental Period	Group	Group	Degrees of Freedom	t-test	Significance
Part II	II	Free Lab	Scheduled Lab	134	2.69	V.S.
		Home Lab	Scheduled Lab	125	2.41	V.S.
		Free Lab	Home Lab	121	0.14	N.S.
Part III	II	Free Lab	Scheduled Lab	134	2.75	V.S.
		Home Lab	Scheduled Lab	125	1.89	S.
		Free Lab	Home Lab	121	0.98	N.S.
TOUS Total	II	Free Lab	Scheduled Lab	134	3.30	V.S.
		Home Lab	Scheduled Lab	125	2.13	S.
		Free Lab	Home Lab	121	1.11	N.S.

The t-test statistic was computed to determine which group contributed to the significance as determined by the F test. This data is shown in Table V. This data indicates that for the second experimental period the free lab and home lab groups scored significantly higher (P = .01 and P = .05, respectively) than the scheduled lab group. When comparing group means for the total TOUS test, the data indicates that the free lab and home labs groups scored significantly higher (P = .01 and P = .05, respectively) than the scheduled lab.

Thus, the analysis of data indicates that for ten tests or parts of tests administered to three treatment groups during two experimental periods, significant differences between groups occurred only three times and these differences occurred during the second experimental period on the Test On Understanding Science.

PART III: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The research conducted in this study was designed to determine whether three different methodological approaches to the laboratory for a general education physical science course would lead to the same behavioral outcomes. The students enrolled in the general education course, PS 214 Physical Science, were randomized into one of three laboratory treatment groups: a highly structured scheduled lab, an audio-tutorial type free lab, or a loosely structured home lab. All three laboratory groups were working toward the same behavioral outcomes. Behavioral changes were assessed through instructor written unit tests and the Test On Understanding Science. Data was obtained for 140 students during the first experimental period (Spring Semester, 1969) and for 193 students during the second experimental period (Fall Semester, 1969). The data were analyzed using an analysis of covariance to determine if any significant differences existed among the three laboratory treatment groups. If the analysis of covariance suggested that significant differences existed among the experimental groups, then a t-test was used to determine significance between groups, or which group was contributing to the significance.

The following findings are based on the data collected through the use of the Instructor Written Tests and the Test On Understanding Science:

1. For the first experimental period beginning January, 1969, no significant differences existed among the laboratory groups in terms of their cognitive knowledge of science or their understanding of science as measured by Instructor Written Tests and TOUS, respectively.

2. For the second experimental period beginning September, 1969, no significant differences existed among the laboratory groups in terms of their cognitive knowledge of science as measured by Instructor Written Tests.

3. For the second experimental period beginning September, 1969, significant differences existed among the laboratory groups in terms of their understanding of science as measured by TOUS.

4. For the second experimental period beginning September, 1969, the free lab and home lab groups scored significantly higher than the scheduled lab groups in terms of their understanding of science as measured by TOUS.

The results of this study indicate that, in general, one type of laboratory approach is as effective in accomplishing the stated objectives as either of the other two approaches to the laboratory. Therefore, the null hypotheses concerning differences in the attainment of the specified cognitive skills as measured by the Instructor Written Tests are accepted.

The findings relative to understandings about science from the two experimental periods are not consistent. This could be attributed to the fact that randomization of students between the two experimental periods was impossible to accomplish, or to the possibility that the experimental treatment was not exactly the same for both periods of study, or characteristics of the sample for spring and fall semesters were different. The first experimental period involved development and implementation of materials while during the second period, refinement and improvement occurred.

The null hypotheses concerning differences in the understanding of science as measured by TOUS can neither be accepted nor rejected (for the entire study). This study does show that alternate type laboratory situations, a free lab or a home lab, are as effective in accomplishing the stated objectives as the type of laboratory normally associated with science courses--the scheduled lab.

The findings of the research project do suggest some alternatives for institutions who are faced with the problem of priority of instructional staff, physical facilities, and budget for instructional materials. The free lab concept required staff time to prepare audiotapes and visuals, but a library of these materials is now available, thus eliminating need for staffing a pre-laboratory session. Furthermore, the laboratory facility might be optimized in terms of usage. Needless to say, the free lab concept offers the student certain advantages in that he is free to meet his laboratory responsibility at a time of his choosing.

The home lab offers even more possibilities for implementing a laboratory with a course which is currently lecture-centered. The home lab concept makes no demands on the physical facilities, and once the design and development of the individual laboratory exercises was completed, the demand on staff time was substantially reduced. Also, because of the nature of the laboratory materials used, the cost of the home lab was minimal.

The researchers feel that there were also certain outcomes for those in the free lab and home lab groups which were not measured by the Instructor Written Tests, and perhaps not by TOUS. The less structured atmosphere characterizing the home lab and free labs seemed to allow the student more freedom to investigate beyond the expectations of the instructors. The students in these treatment groups often indicated a kind of mental emancipation, often raising questions which suggested that they had done more than "what we wanted". Possibly this is what contributed to the significant difference in scores on the Test On Understanding Science for the second experimental period.

At the present time, there are two nationally developed, laboratory based courses in physical science for the non-science major. Each of those projects has implemented the concept of take-home laboratories. In fact, one of the projects has developed an attache case so that the laboratory materials might be carried easily beyond the science classroom. The findings of this research study would support the validity of this venture by these two curricular groups. To date there was no research data in existence to support such a home lab concept.